Influence of renal insufficiency on limb loss and mortality after initial lower extremity surgical revascularization

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Objective: **Limb loss after lower extremity surgical revascularization occurs relatively frequently in patients receiving dialysis. The goal of the present study was to determine whether patients with milder degrees of renal insufficiency are also at risk for this complication.**

Material and methods: **This cohort study was carried out at the Department of Veterans Affairs (VA). The study sample consisted of 9932 patients undergoing an initial surgical revascularization procedure between October 1, 1995, and September 30, 2000, recorded by the VA National Surgical Quality Improvement Program (NSQIP). We examined the occurrence of major amputation within 1 year of lower extremity surgical revascularization by level of renal function.**

Results: **Eleven percent of study patients underwent major lower extremity amputation within 1 year of NSQIP-documented lower extremity revascularization surgery: 10% (739 of 7335) of patients with normal renal function, 11% (251 of 2210) of patients with moderately reduced renal function, 12% (24 of 205) of patients with severe renal insufficiency, and 29% (53 of 182) of patients receiving dialysis. After adjustment for demographic characteristics and comorbid conditions, only patients receiving dialysis were at significantly increased risk for amputation, compared with patients with normal renal function (odds ratio, 2.46; 95% confidence interval, 1.74-3.47; $P < .001$). Compared with all other veterans undergoing bypass procedures, patients receiving dialysis were more likely to have a wound infection; a diagnostic code for lower extremity gangrene, infection, or ischemic ulceration; an elevated white blood cell count; and preoperative sepsis at the time of initial revascularization. In addition, they were more likely to have a preoperative hospital stay longer than 1 week, undergo concurrent minor amputation, and undergo an outflow (vs inflow) procedure.**

Conclusion: **Only patients receiving dialysis, and not patients with milder degrees of renal insufficiency, appear to be at higher risk for limb loss after revascularization, compared with patients with normal renal function. Further studies are needed to determine why patients receiving dialysis are at a singularly increased risk for limb loss after lower extremity revascularization and whether their more frequent presentation with limb-threatening infection at the time of revascularization reflects late presentation for surgery or a more rapid course of peripheral arterial disease in this patient group. (J Vasc Surg 2004;39: 709-16.)**

Numerous retrospective case series have reported relatively low limb salvage rates after lower extremity surgical revascularization in patients with renal insufficiency compared with those with normal renal function.[1-15] The relatively frequent requirement for amputation after lower extremity revascularization in this group[16] is a well-recognized phenomenon that raises important questions about the appropriateness of revascularization over primary amputation.[5]

Many previous studies that specifically examined the contribution of renal insufficiency to limb salvage rates after revascularization either focused solely on patients receiving dialysis or grouped patients receiving dialysis with renal transplant patients and those with milder forms of renal insufficiency.[1-15] Thus it is not known whether patients with milder forms of renal insufficiency are also at increased risk for limb loss after lower extremity revascularization. Many of the factors that appear to predispose patients receiving dialysis to atherosclerotic events are also applicable in patients with milder degrees of renal insufficiency.[17] Furthermore, for a variety of surgical procedures, including lower extremity revascularization, the incidence of many postoperative complications is increased, not only for patients receiving dial-

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ysis but also for patients with mild or moderate renal insufficiency.[18-22]

We used prospectively collected data from the Department of Veterans Affairs (VA) National Surgical Quality Improvement Program (NSQIP), linked to International Classification of Diseases, ninth revision (ICD-9)–coded VA hospital administrative data for the same veterans, to study the association of renal insufficiency with the incidence of early major lower extremity amputation, defined as, amputation at the level of the ankle or higher occurring within 1 year of lower extremity bypass graft surgery. We hypothesized that there would be a high incidence of post-revascularization amputation in patients receiving dialysis, but that in addition there would be a graded increase in risk for amputation after lower extremity revascularization with advancing degrees of renal insufficiency. We also hypothesized that the association of renal insufficiency with early amputation might be explained in part by the presence among these patients of a more distal pattern of lower extremity disease at revascularization or by their more frequent presentation with advanced lower extremity soft tissue injury at revascularization.

METHODS

Databases. Index surgical revascularization procedures were identified with the VA NSQIP database, an ongoing quality management initiative for surgical care. Since its inception on January 1, 1994, NSQIP has prospectively collected data on most major surgeries occurring at VA medical centers (VAMCs) across the United States. A detailed account of NSQIP study design and validation methods is provided elsewhere.[23] One hundred twenty-three VAMCs participate in NSQIP. Procedures performed with the patient under general, spinal, or epidural anesthesia are eligible for inclusion in NSQIP. Patients are enrolled in NSQIP at surgery, at which time data on baseline clinical and demographic characteristics are obtained from the medical record, patient interview, or the surgeon caring for the patient. Preoperative laboratory values are transmitted electronically from the VAMC decentralized hospital computer system (VistA) to the coordinating center at the Denver VA Medical Center and the University of Colorado Health Outcomes Program. Patients are then surveilled prospectively into surgery and for 30 days after surgery by surgical clinical nurse reviewers. Data regarding the surgery and postsurgical complications occurring within 30 days are ascertained by these nurse reviewers, using the medical record, surgeon interview, and patient follow-up by letter or telephone call. The medical record is reviewed for 100% of patients undergoing a NSQIP-recorded procedure. Unlike hospital discharge databases, in which data capture is frequently incomplete and lacking in clinical detail, NSQIP has a managerial and reporting structure designed to enable continuous monitoring and enhancement of surgical care in VAMCs.[23] Nurse reviewers receive annual training in NSQIP operations, and are required to take proficiency examinations at regular intervals. These nurses are not part of the surgery services at the local VAMC where they are based, but operate within the structure of NSQIP. A network of regional NSQIP nurse leaders and a system of biweekly conference calls are in place to support nurse reviewers. Finally, to maintain high-quality data collection, NSQIP periodically conducts site visits at individual centers.

Amputations occurring after initial revascularization were identified with the VA administrative database[24] (ie, the Patient Treatment File Surgery and Procedure files, Extended Care Surgery and Procedures files, and non-VA Surgery and Procedures files) and NSQIP. Non-VA Surgery and Procedure files contain information about episodes of care provided for veterans by non-VA institutions under VA contract. Patient deaths were ascertained with the Beneficiary Identification and Records Locator System death records.[25,26] The study was approved by the Research and Development Committee of the San Francisco VA Medical Center and by the Committee on Human Research at the University of California, San Francisco.

Sample selection. The following database search was designed to identify all lower extremity surgical revascularization procedures recorded as principal procedures in the NSQIP database from October 1, 1995, through September 30, 2000, in which the patient had not undergone a previous major amputation or lower extremity revascularization in a VAMC. The study did not include percutaneous revascularization procedures. Initially we searched the NSQIP database for patients undergoing their first lower extremity surgical revascularization between October 1, 1993, and September 30, 2000. The NSQIP search was conducted with current procedural terminology (CPT) codes for lower extremity surgical revascularization. We searched for the first occurrence of at least one of the CPT codes identified, and retained for further analysis the chronologically first bypass procedure performed between October 1, 1995, and September 30, 2000. Patients who underwent a NSQIP-recorded major lower extremity amputation, either as a principal or nonprincipal procedure, after January 1, 1993, and before or at the same time as the index revascularization procedure were excluded from the analysis.

Because not all surgical procedures recorded in the administrative database are captured by NSQIP, we excluded patients who had undergone a previous lower extremity revascularization or major amputation in the VA by also searching VA administrative databases for previous revascularization or major amputation procedures, including nonprincipal procedures, from October 1, 1993, 2 years before the beginning of the study period. ICD-9 procedure codes were used to identify these procedures.

Definition of renal function. A single preoperative serum creatinine concentration measurement was available for most patients in the NSQIP database. In addition, nurse reviewers, who have access to the medical record, also recorded whether patients experienced preoperative acute renal failure, defined by NSQIP as rapidly rising creatinine concentration greater than 3 mg/dL and oliguria. Glomerular filtration rate (GFR) was calculated for each patient with the abbreviated Modification of Diet in Renal Disease formula, which predicts GFR on the basis of serum creatinine concentration, age, gender, and race.[27]

Patients were grouped according to level of renal function: normal or mildly reduced renal function (estimated GFR, ≥60 mL/min/1.73 m^2), moderate renal insufficiency (estimated GFR, 30-59 mL/min/1.73 m^2), severe renal insufficiency (estimated GFR, <30 mL/min/1.73 m^2), and dialysis-dependent renal failure. This classification is similar to the definition recommended by the National Kidney Foundation Dialysis Outcome Quality Initiative (NKF-DOQI) guidelines for chronic kidney disease[28], with one exception: to draw comparisons between patients receiving dialysis and those not receiving dialysis, the small number of patients with estimated GFR <15 mL/min/1.73 m^2 but not receiving dialysis were included in the group with severe renal insufficiency (estimated GFR, <30 mL/min/1.73 m^2) and not included with patients receiving dialysis in a "kidney failure" category, as suggested by NKF-DOQI guidelines. We excluded from the analysis all patients who had preoperative acute renal failure, to include only patients likely to have chronic renal insufficiency.

Outcome variable. The outcome of interest in this analysis was the occurrence of a major nontraumatic lower extremity amputation during the first post-revascularization year, defined as any amputation at the level of the ankle or above, recorded as a principal or nonprincipal procedure either in NSQIP or the VA administrative database.

Baseline patient demographic characteristics and comorbid conditions. Patient demographic characteristics included age, race, and sex. Age was dichotomized at the median value of 66 years, and patient race was defined as black versus non-black. Comorbid conditions prospectively recorded by NSQIP coordinators before the procedure included diabetes (categorized according to whether the patient was receiving an oral hypoglycemic agent or daily insulin), chronic obstructive pulmonary disease, history of congestive heart failure (CHF) during the month before surgery, history of stroke with neurologic deficit, current smoking (within 1 year of the procedure), and current alcohol use.

Patient clinical status at surgery. Variables that indicated the patient's clinical findings at revascularization that we postulated might be part of the causal pathway for amputation after revascularization included the presence of wound infection at surgery; postoperative diagnosis recorded by the surgeon of any one of the following conditions: gangrene, foot cellulitis or abcess, osteomyelitis, foot ulceration (ICD-9 codes 440.23, 440.24, 681.1, 707.1, 707.8-707.9, 785.4); white blood cell count at surgery; preoperative sepsis; need for an emergency procedure (procedures were deemed emergencies in NSQIP if referred to as "emergent" by either the surgeon or the anesthesiologist); pre-revascularization hospital length of stay, dichotomized a priori at the 75th percentile (7 days); whether the patient underwent a concurrent minor amputation (toe or through foot) under the same anesthetic as the revascularization procedure; and type of revascularization procedure performed. Revascularization procedures were classified as inflow procedures if they provided blood to the inguinal vessels (common femoral, superficial femoral, or profunda femoris arteries), and as outflow procedures if they provided blood supply to or beyond the popliteal artery. Outflow procedures were further classified into popliteal and subpopliteal (to the tibial or peroneal arteries) procedures. CPT codes were used to categorize revascularization procedures in this way.

Statistical analysis. Baseline patient characteristics across renal insufficiency categories were compared with the reference category of persons with normal or mildly reduced renal function with the χ^2 test. We used logistic regression analysis to measure the association of renal function with the occurrence of at least one major lower extremity amputation within 1 year of revascularization, adjusted for patient baseline demographic characteristics and comorbid conditions. We also used logistic regression analysis to measure the association of variables indicating preoperative clinical presentation with dialysis status, to explore the hypothesis that high post-revascularization amputation rates among patients receiving dialysis might reflect more advanced limb ischemia or limb-threatening infection at revascularization. Each analysis was adjusted for demographic characteristics and comorbid conditions that were associated with both renal insufficiency and the particular covariate, to adjust for confounding. We then measured the association of renal insufficiency with early amputation further adjusted for covariates in the aforementioned analysis that were independently associated with dialysis status. Patients with missing data for any one variable were excluded from multivariable analysis. We repeated our analysis, excluding all patients who died during the study period, to confirm that inclusion of patients who died did not bias the results.

RESULTS

We identified 10,478 principal procedure lower extremity surgical revascularizations in NSQIP in which the patient had not undergone a previous lower extremity revascularization or major amputation within the VA recorded either in NSQIP or in the VA administrative database. Of these, 3 patients were excluded because of inaccurate operative or death dates and 489 patients were excluded because they lacked data regarding preoperative renal function, either preoperative serum creatinine concentration or an indication that the patient was receiving dialysis at the time of surgery. Fifty-four of the remaining patients had preoperative acute renal failure, defined by NSQIP as creatinine concentration rapidly rising to greater than 3 mg/dL and oliguria, and were excluded from the analysis. The study sample thus consisted of 9932 patients undergoing their first lower extremity revascularization in the VA between October 1, 1995, and September 30, 2000.

Among study patients, 7335 patients (74%) had normal or mildly reduced renal function (GFR ≥60 mL/min/1.73 m^2), 2210 patients (22%) had moderately reduced renal function (GFR 30-59 mL/min/1.73 m^2), 205 pa-

Table I. Baseline demographic data, comorbid conditions, and type of revascularization procedure

	Level of renal disease			
Variable (percent data missing)	*Normal (n = 7334)*	*Moderate (n = 2210)*	*Severe (n = 205)*	*Dialysis (n = 182)*
Demographic data				
Age >66 y (%)	41	68*	69*	49†
Male gender (%)	99	98*	97‡	98
Black race (4%) (%)	17	12*	11†	43*
Comorbidity				
Diabetes, with oral hypoglycemic agent (%)	16	17	16	15
Diabetes, with daily insulin (%)	15	25*	37*	44*
CHF (%)	3	7*	10*	10*
Stroke with neurologic deficit (%)	9	13*	14†	14†
COPD (%)	19	22†	19	16
Alcohol user (<1%) (%)	16	8*	9†	2*
Smoker (%)	63	45*	41*	25*
Type of procedure				
Inflow (%)	50	41*	36*	17*
Outflow, popliteal artery (%)	29	31†	29	32
Outflow, subpopliteal (%)	22	29*	35*	52*

CHF, Congestive heart failure; *COPD*, chronic obstructive pulmonary disease.
P values pertain to chi^2 tests comparing each renal insufficiency category with the referent category of those with normal or mildly reduced glomerular filtration rate. Percentages for type of revascularization procedure may not total 100%, because of rounding.
*$P \leq .001$.
†$P \leq .05$.
‡$P \leq .01$.

Table II. Univariate and multivariate logistic regression analysis of amputation within 1 year of revascularization

	Amputation			
Level of renal function	*Unadjusted OR*	*CI*	*Adjusted* OR*	*CI*
Normal or mildly reduced (GFR ≤60 mL/min/1.73 m^2)	1.00		1.00	
Moderate (GFR 30-59 mL/min/1.73 m^2)	1.14	0.98, 1.33	0.94	0.80, 1.10
Severe (GFR <30 mL/min/1.73 m^2)	1.18	0.77, 1.82	0.84	0.54, 1.32
Dialysis-dependent	3.67	2.64, 5.09†	2.46	1.74, 3.47†

GFR, Glomerular filtration rate; *OR*, odds ratio; *CI*, 95% confidence interval.
*Multivariate analysis is adjusted for all baseline demographic data and comorbid conditions that differed across renal function categories and were associated with outcome (ie, age, race, diabetes, CHF, stroke, alcohol use).
†$P \leq .001$.

tients (2%) had severe renal insufficiency but were not receiving dialysis (GFR <30 mL/min/1.73 m^2), and 182 patients (2%) were receiving dialysis at the time of revascularization. Characteristics of the study population according to degree of renal function are shown in Table I. Percentage of patients with diabetes receiving daily insulin, with CHF, and with stroke with neurologic deficit tended to increase along with degree of renal dysfunction, whereas percentage of patients who were alcohol users or smokers tended to decrease with worsening renal function. Percent of African Americans was higher in the dialysis group. Finally, as the degree of renal insufficiency increased, there was a progressive decrease in the percentage of inflow procedures and an increase in the percentage of subpopliteal outflow procedures. The percentage of popliteal outflow procedures (femoropopliteal) was slightly higher for those with moderate renal insufficiency but similar for all other groups.

The incidence of major lower extremity amputation, death, and either of these outcomes during the year after revascularization for each renal function group is shown in the Fig. Amputation rate was similar across all renal insufficiency groups except for patients receiving dialysis, in whom the amputation rate was almost threefold that among other groups. Death rates increased with worsening renal function. Consequently, more than half of all patients receiving dialysis either died or underwent major lower extremity amputation, or both, during the year after lower extremity revascularization. Univariate and multivariate logistic regression analyses of level of renal function with the outcome of amputation within 1 year of lower extremity revascularization are shown in Table II. In unadjusted

Table III. Prevalence and association of clinical findings at revascularization, with dialysis status

Variable (% data missing)	*Prevalence among patients receiving dialysis*	*Prevalence among patients not receiving dialysis*	*Adjusted OR*	*CI*	P
Wound infection (%)	65	28	3.22	2.30, 4.50*	≤.001
Postoperative diagnostic code for lower extremity infection or gangrene† (%)	29	13	2.01	1.43, 2.83‡	≤.001
WBC > 12,000 (<1%) (%)	25	10	2.97	2.09, 4.21§	≤.001
Preoperative sepsis (%)	4	<1	3.89	1.72, 8.80‖	≤.001
Emergency procedure (%)	7	5	1.62	0.91, 2.90¶	
Preoperative hospital stay >7 d (<1%) (%)	37	22	1.50	1.09, 2.06#	≤.05
Inflow procedures (%)	17	47	0.33	0.22, 0.50**	≤.001
Outflow procedures, popliteal (%)	32	29	1.11	0.80, 1.53**	
Outflow procedures, subpopliteal (%)	52	24	2.13	1.55, 2.93**	≤.001
Concurrent minor amputation (%)	10	4	1.71	1.02, 2.87††	≤.05

WBC, White blood cell count; *ICD-9*, International Classification of Diseasses, ninth revision; *CHF*, congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *OR*, odds ratio; *CI*, 95% confidence interval.
*Adjusted for age, race, diabetes, CHF, COPD, and stroke.
†ICD-9 codes 440.23, 440.24, 681.1, 707.1, 707.8-707.9, or 785.4.
‡Adjusted for age, diabetes, race, and COPD.
§Adjusted for diabetes, CHF, COPD, and smoking.
‖Adjusted for sex and diabetes.
¶Adjusted for diabetes, CHF, COPD, and smoking.
#Adjusted for age, race, diabetes, CHF, stroke, and alcohol use.
**Adjusted for age, race, diabetes, CHF, smoking, and alcohol use.
††Adjusted for age, race, diabetes, COPD, stroke, and alcohol use.

Table IV. Association of dialysis status with amputation after revascularization

Model	*Odds ratio*	*95% confidence interval*	P
Unadjusted	3.54	2.55, 4.90	<.001
Adjusted for demographic data and comorbidities*	2.51	1.79, 3.53	<.001
Further adjusted for preoperative condition†	1.67	1.17, 2.37	.005

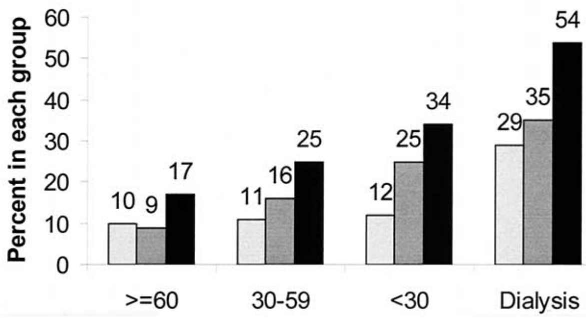
*Adjusted for all demographic data and comorbid conditions associated with amputation within 1 year of revascularization (ie, age, race, diabetes, CHF, stroke, alcohol use).
†Additionally adjusted for all preoperative and operative data associated with both dialysis status and amputation (ie, wound infection, postoperative diagnostic code) for gangrene or lower extremity infection, preoperative white blood cell count, preoperative sepsis, hospital stay >7 days, concurrent minor amputation, and type of procedure (ie, inflow procedure vs outflow procedure; popliteal vs outflow procedure, subpoplitcal).

analysis and after adjustment for baseline demographic characteristics and comorbid conditions that were associated with the outcome in univariate analysis (age, race, diabetes, history of CHF, history of stroke, and alcohol use), only dialysis-dependent renal failure, and not milder levels of renal insufficiency, was significantly associated with amputation after lower extremity revascularization.

To test the hypothesis that high post-revascularization amputation rates among patients receiving dialysis might reflect more advanced limb ischemia or limb-threatening infection at revascularization, we examined the association of dialysis status with variables indicating patient clinical findings at surgery (Table III). Each analysis is adjusted for all other demographic characteristics and comorbid conditions that were also associated with the specific outcome examined. Patients receiving dialysis were more likely to have a wound infection; a postoperative ICD-9 diagnosis of gangrene, ulceration, or lower extremity infection; an elevated white blood cell count; preoperative sepsis; requirement for a more distal procedure; requirement for concurrent minor amputation; and pre-revascularization hospital stay of more than 7 days, even after adjustment for confounders. The association of dialysis status with amputation after revascularization was substantially attenuated by inclusion of these variables (Table IV). The results of these analyses did not change substantially when we excluded patients who died.

DISCUSSION

There is an extremely high risk for amputation within the first year after lower extremity revascularization in patients receiving dialysis (29% vs 10% in patients with normal or mildly reduced renal function), which is not shared by patients with milder forms of renal insufficiency. Overall, fewer than 50% of patients receiving dialysis who underwent lower extremity revascularization survived



Percentage of patients in each group with renal insufficiency with amputation *(light gray bars)*, death *(dark gray bars)*, or either outcome *(black bars)* during the year after lower extremity revascularization.

longer than 1 year without undergoing at least one major amputation. Since our sample included only the select group of patients who had not previously undergone amputation or revascularization, overall rates of limb loss after revascularization, including repeat and second procedures, are probably even higher than reported here.

The lack of a graded increase in risk for amputation after lower extremity revascularization with worsening renal function is somewhat surprising, because patients with mild to moderate renal insufficiency are at increased risk for adverse outcomes such as death and cardiovascular complications after both lower extremity revascularization[29] and other surgeries.[18-22] Furthermore, many of the same processes that predispose to atherosclerosis in patients receiving dialysis are also ongoing in patients with milder forms of renal insufficiency.[17] The singularly high incidence of limb loss after revascularization in patients receiving dialysis may be partially explained by the higher prevalence of insulin-requiring diabetes and requirement for more distal procedures in this group. However, patients receiving dialysis were still at increased risk for limb loss after adjustment for diabetes and type of procedure, in addition to other demographic and clinical characteristics. Alternative explanations include the presence of more severe underlying comorbid conditions, in particular, diabetes; or the presence among dialysis patients of a form of atherosclerosis that is more likely to progress or for which revascularization is less appropriate (eg, more distal disease, higher prevalence of vascular calcification), impaired lower extremity wound healing associated with renal insufficiency,[30] or greater tendency for advanced lower extremity soft tissue injury at the time of lower extremity revascularization.

Our findings raise the question of whether worse lower extremity outcomes are seen in patients receiving dialysis as the result of the presence of more advanced soft tissue infection. This may reflect the fact that these procedures are being performed relatively late in the course of lower extremity disease, when there is already extensive soft tissue injury. In a case-control study of lower extremity revascularization, Reddan et al[31] reported that patients receiving dialysis were more likely than control subjects matched for age, sex, and diabetes to have gangrene or ulceration, as compared with rest pain and claudication. In the present study, even after adjustment for confounding factors, patients receiving dialysis were more likely to have wound infection, elevated white blood cell count, and preoperative sepsis; a diagnosis of gangrene or lower extremity ulcer or infection by ICD-9 code; preoperative hospital stay lasting more than 1 week; and to require concurrent minor amputation. These findings probably indicate a higher prevalence of limb-threatening infection in the dialysis group compared with the non-dialysis group undergoing revascularization.

There are several possible explanations for the more frequent finding of advanced lower extremity soft tissue injury in patients receiving dialysis. It is possible that this could reflect a relative reluctance on the part of clinicians caring for these patients to subject them to the risks associated with lower extremity revascularization surgery. This may be particularly true at earlier stages of disease, in which the perceived risk-benefit ratio of revascularization may be less favorable than later in the disease course in this group at high surgical risk. Alternatively, the more frequent finding of advanced soft tissue infection in patients receiving dialysis may reflect more rapid disease progression in this group, perhaps outstripping the normal pace of disease recognition and surgical referral. Further studies are needed to determine which, if any, of these processes might explain the higher prevalence of limb-threatening infection in this group at revascularization.

After adjustment for type of revascularization procedure and factors indicative of degree of soft tissue injury, such as wound infection, diagnostic code for gangrene or lower extremity ulceration or infection, white blood cell count, or sepsis, the association of dialysis status with amputation after revascularization was considerably attenuated. This suggests that poor outcomes after revascularization in this group may in part be accounted for by the nature of clinical findings at revascularization. Worse outcomes in patients receiving dialysis, even after adjustment for these covariates, may reflect clinical details not measured by NSQIP, such as severity of soft tissue damage, details of vascular anatomy, presence of vascular calcification, or impaired wound healing.

A limitation of the study is that it may not be possible to generalize our results to non-veteran populations and to women in particular. However, the large, multicenter study design and prospective data collection by NSQIP offer advantages over previous studies based on single-institution experience. A second limitation is that outcomes occurring outside the VA were not captured by the present analysis. This may have resulted in inclusion of secondary revascularization procedures in the study sample and underestimation of post-revascularization amputation rates. However, we do not think this is a major concern, because post-revascularization amputation rates reported here in patients receiving dialysis are consistent with those reported elsewhere. More concerning would be differential loss to follow-up across renal insufficiency categories. However, we would anticipate that loss to follow-up would be more common among patients receiving dialysis, because they have higher rates of dual Medicare-VA use compared with patients not receiving dialysis (D.M. Hynes, K. Stroupe, and P. Colin; personal communication, May 2002). Thus differential loss to follow-up would likely bias our results toward, rather than away from, the null hypothesis; that is, the incidence of amputation after revascularization reported here for patients receiving dialysis is more likely an underestimate than that for other groups. Finally, analysis of indication for surgery was limited to ICD-9 diagnostic code information rather than more detailed chart data. This may have led to misclassification of surgical indication, owing to the nonspecific nature of ICD-9 coding. However, inclusion in the analysis of other variables that indicate presence of infection or tissue damage, such as preoperative wound infection and preoperative white blood cell count, probably overcomes this limitation.

In conclusion, unlike patients with milder degrees of renal insufficiency, patients receiving dialysis have a high incidence of amputation within 1 year of lower extremity revascularization that is not explained by a higher prevalence of demographic characteristics and comorbid conditions associated with the complication. This finding is particularly disturbing given the high post-revascularization mortality in this group. Poor outcomes after lower extremity revascularization in patients receiving dialysis may be explained in part, but not completely, by the more frequent clinical finding of limb-threatening infection.

Further studies are needed to determine why patients receiving dialysis are at singularly increased risk for limb loss after lower extremity revascularization and why they are more likely to have limb-threatening soft tissue damage at revascularization. Specifically, such studies should attempt to determine whether this clinical finding reflects a different or more aggressive disease course versus differences in clinical decision-making, such as later referral for surgery. Such information would be helpful in identifying target areas for interventions to improve outcomes in patients with limb ischemia who are receiving dialysis. In addition, decision making in this area should clearly take into account quality of life, because these patients experience both high amputation rates and high mortality after lower extremity revascularization.

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